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CIVIL ENGINEERS

SEPTEMBER, 1954

INCINERATION

Report of a Subcommittee of the Committee on Refuse Collection and Disposal of the Sanitary Engineering Division

SANITARY ENGINEERING DIVISION

{Discussion open until January 1, 1955}

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INCINERATION

REPORT OF A SUBCOMMITTEE OF THE COMMITTEE ON REFUSE COLLECTION AND DISPOSAL OF THE SANITARY ENGINEERING DIVISION

This report on Incineration is one of a series produced by Subcommittees of the Sanitary Engineering Division's Committee on Refuse Collection and Disposal. Other subcommittees have reported on Collection; Dumping and Landfill; Hog Feeding; Reduction; Composting and Grinding; State Activities; and Fiscal Aspects. These reports are being published as separates as they are edited. While not consecutively issued or numbered, the reports will form a series representing the final report of the Committee on Refuse Collection and Disposal.

The committee consisted of:

Henry W. Taylor, Chairman
Norman W. Nester
Newell L. Nussbaumer
Sol Pincus
Charles L. Senn
V. M. Ehlers
Charles L. McGauhey

Members of the Subcommittee concerned are listed at the end of this and the other Subcommittee reports.

FOREWORD

In 1901, M. N. Baker made the following and now classic statement:

"In no branch of municipal service has so little progress been made in the United States as in the disposal of garbage. Why do such conditions exist? First, because the sanitary collection and disposal is appreciated neither by the general public nor the city officials; second, because it is seldom recognized that the problems incident to final disposal are largely engineering in character and therefore should be entrusted to engineers."

Mr. Baker's statement could be enlarged in scope by substituting "refuse" for "garbage" and adding emphasis to the need for engineering technique and administration in collection as well as in disposal methods.

Activities of this Committee on Refuse Collection and Disposal since its inception may be briefly summarized as follows:

In 1935 the Sanitary Engineering Division appointed a "Committee on Technical Aspects of Refuse Disposal" and this Committee functioned until January, 1942, during which period four reports were submitted and abstracted in Civil Engineering. The final report of this Committee stated that:

> "due to the unusual activity of members of the Committee and on account of the lack of general interest in the subject under consideration at this time, together with a feeling on the part of the Committee Members that the subject is not particularly well adapted to Committee action, it is recommended that this Committee be discontinued."

The "unusual activity" of Members of the Committee still exists. Any lack of general interest in this subject has been replaced by the pressing necessity of solving a municipal problem which places increasing demands on public officials and engineers. A new Committee was appointed in 1947 and a progress report was submitted by the Chairman, Rolph Eliassen. This progress report outlined many of the facets of this subject and the need for application of engineering technique and administration.

At the 1949 meeting of this Society, a report was submitted by the Committee on "Advancement of Sanitary Engineering," which recommended the collaboration of the personnel from other technical organizations in the activities of Committees working on projects of broad scope. The recommendation met with quick approval and the present Committee has attempted to put these recommendations into tangible form by introducing Subcommittes who operate as task groups under the leadership of the personnel of the base Committee.

A report by the Committee in January, 1950 confined itself to the organization of the Committee and Subcommittees with a prospectus of objectives. A Progress Report was submitted in October, 1952 and included the efforts of seven Subcommittees.

This report for 1953 may be considered as the final report of the Committee with the objectives originally stated by this Committee. The increased activity in research, in design and operation are leading to an extensive program of literature emanating from individuals, colleges, institutions and commissions and any attempt by this Committee to include all this data would be futile and a subsequent report would be largely a bibliography of this literature. In other words, present activities have extended beyond the scope of the Committee and involve a volume of current literature from various sources which are available from their original source.

This report is actually individual reports of the seven task groups acting as Subcommittees. The Chairman has considered that each group contains acknowledged experts within the scope alloted to it and has not, in general, modified or condensed the reports as submitted by these separate Subcommittees. He has also considered that it would be impracticable for the base committee as a whole to attempt to pass on or modify the work of the individual groups since the scope of these groups includes such a varied field.

The Chairman has reduced the personnel of various Subcommittees, as stated in this report, to those who have been able to devote time and submit data to their various Subcommittee Chairmen. The Chairman wishes to express his appreciation of the cooperation of the Committee and Subcommittee members.

HENRY W. TAYLOR, Chairman

ASCE Committee on
Refuse Collection and Disposal

INCINERATION

The report of this Committee has been confined to the indications of current trends in incinerator installations in the last two years, and to the discussion of current problems and current demands imposed on modern design.

The Committee considers that certain trends have crystallized in recent years as illustrated by the following tabulation of typical, recent incinerator installations and their main characteristics. The letters at the head of the various columns refer to the following:

M Municipal

I Industrial

T Tons per 24 hours

PC Pit and Crane

FD Floor or direct dump

C Circular furnace with revolving cone design

R Rectangular furnace design

FA Special equipment for fly ash interception

P Power production from products of combustion

Notes: Relate to special features not included under headings of the tabulation. These notes have the same number as the installation.

Only those industrial installations which are of sizeable capacity or of special design have been included in the tabulation. Installations under contract or construction are included as they also indicate design trend.

TABULATION OF RECENT INSTALLATION

1952-1953

INSTALLATION	M	I	T	PC	FD	C	R	FA	P	Notes	
1. Atlantic Refining Co. Phila., Pa.		X				X			X	X	1
2. Baltimore, Md.	X		800	X			X			X	2
3. Bloomburg, Pa.	X		60		X	X				X	3
4. Buffalo, N.Y.	X		400	X		X				X	4
5. Calgary, Canada	X		240	X		X					5
6. Cheviot, Ohio	X		60		X		X				6
7. Cincinnati, Ohio	X		500	X		X					7

TABULATION OF RECENT INSTALLATION (CONT.)

1952-1953

INSTALLATION	M	I	T	PC	FD	C	R	FA	P	Notes	
8. Columbia, So. Ch. Corp. Barberton, Ohio		X								X	8
9. DuPont, Texas		X								X	9
10. DuPont, Fla.		X								X	10
11. Edmonton, Canada	X		360	X		X					11
12. Erie, Pa.	X		200	X		X					12
13. Federal Reserve Banks (3 plants)		X						X		X	13
14. Fort Lauderdale, Fla.	X		250	X		X					14
15. Fort Worth, Texas	X		250	X				X		X	15
16. Glendale, Calif.	X		100	X		X		X		X	16
17. Gloucester City, N.J.	X		60			X				X	17
18. Gretna, La.	X		100	X		X					18
19. Green Bay, Wis.	X		60		X		X				19
20. Harrison, Town of N.Y.	X		150		X	X					20
21. Hartford, Conn.	X		600	X		X				X	21
22. Hempstead, Town of N.Y.	X		700	X		X		X	X		22
23. Kenosha, Wis.	X		120		X		X				23
24. Lawrence, Mass.	X		300	X						X	24
25. Lima, Ohio	X		200		X		X				25
26. Long Beach, N.Y.	X		200	X		X					26
27. Los Angeles, Calif.	X		100	X		X					27
28. Mayaguez, Puerto Rico	X		60			X					28
29. Merck & Co., Rahway, N.J.		X	90							X	29
30. Merck & Co., Danville, Va.		X								X	30
31. Miami, Fla.	X		900	X		X		X	X		31
32. Milwaukee, Wis.	X		300	X			X			X	32
33. Milwaukee, Wis.	X		300	X		X		X			33
34. Minn. Paint Co., Fort Wayne, Ind.		X								X	34
35. Montreal, Canada 2 plants, each	X		500	X		X					35
36. National Gypsum Co., Alexandria, Ind.		X								X	36
37. North Hempstead, Town of N.Y.	X		250	X		X				X	37
38. Omaha, Neb.	X		375	X			X			X	38
39. Patrick Air Force Base, Cocoa, Fla.		X								X	39
40. Pennsuaken, Town of N.J.	X		60			X				X	40
41. Philadelphia, Pa.	X		300			X		X		X	41
42. Philadelphia, Pa.	X		250	X		X				X	42
43. Regina, Canada	X		120		X	X					43
44. Rochester, N.Y.	X		600	X		X		X			44
45. Rochester, N.Y.	X		450	X		X		X			45
46. Rocky River, Ohio	X		50		X		X				46
47. Saginaw, Mich.	X		60			X				X	47
48. St. Louis Park, Minn.	X		150		X		X			X	48
49. Toronto, Canada	X		900	X		X					49
50. Vitro Corp. Sheffield Dam. Ala.		X								X	50
51. Washington, D.C.	X		500	X			X			X	51
52. Westmount, Canada	X		150		X	X					52
53. Worcester, Mass.	X		450	X		X				X	53

Notes Supplementing Tabulations

1. Incinerates filter cake from waste water treatment plant. Rotating hearth. Waste heat boiler.
2. The Baltimore plant has been equipped with stoking grates, raising its design capacity of 600 T/D to over 800 T/D.
3. Designed to burn dried sludge also.
4. Furnaces supplied with over-fire air.
8. Designed for phosgene gas.
9. This plant designed for chemical wastes.
10. This plant is of special design for chemical wastes.
13. Destroys cancelled currency.
15. Electrically operated charging gates. Truck roads under ash removal floor and combustion chamber for removal of residue and fly ash.
16. Spray towers for fly ash control.
17. Special combination sludge and refuse incinerator. Monorail Crane.
21. Electrically operated charging gates.
24. Electrically operated charging gates.
29. Designed for plant refuse, special chemical wastes and large quantities of solvents. Monorail Crane.
30. Designed for calcining filter aid, and destruction of chemical sludge, rubbish and chemical solvents.
32. Equipped with stoking grates.
34. Designed for varnish fumes.
36. Designed for liquid starch solutions.
37. Electrically operated charging gates.
38. Equipped with stoking grates.
39. Designed for water-aniline mixture.
40. An addition to an old Decarie plant.
41. Replacement of rectangular furnaces.
42. Originally Decarie; replaced by circular furnaces; this installation represents additional circular furnace capacity.
46. Multiple hearth for vacuum filtered primary treatment sewage sludge. Charged by belt conveyor.
47. Equipped with stoking grates.
49. Special installation for mixtures of phosphorus, water, waste oil and sludge.
50. Stoking grates under consideration.
52. Bids received.

From the table it will be noted that of the forty two municipal installations listed, nine have a capacity of 500 tons per 24 hours or greater, with two installations of 900 tons per 24 hours capacity. Of these same installations only eleven have a capacity of 100 tons or less and a considerable number of installations have a capacity range between 100 and 400 tons per 24 hours. Of thirty seven municipal installations about which the table gives data as to handling method, twenty seven are of the pit and crane type and ten are of the floor or direct dump design.

It will be noted that the circular furnaces predominate and that special equipment for fly ash interception has been introduced in nine installations. Special industrial applications are rapidly developing and

combustion utilized to dispose of these wastes.

The notes following the tabulation refer to use of electric drive for charging gates and to the use of stoking grates for rectangular furnaces. Only three installations develop power from the products of combustion but even this small number represents a large increase in power production within the period of a few years. However, power production will be limited to the larger plants and to appropriate local conditions which provide use for the power at favorable rates or credit.

In the last few years, the trend is toward:

a. Increased use of incineration.
b. Larger installations.
c. Circular furnaces.
d. Pit and crane charging even for the smaller plants.
e. Fly ash control.
f. Power production where applicable.
g. Addition of refuse pits, charging apparatus, and new units to existing plants.
h. Improvements in material handling apparatus—into and out of furnaces.

COMMENTS ON INCINERATOR PROBLEMS, DESIGN AND OPERATION

Measurement of Refuse

The Committee as a whole is recommending that more uniform data be available on the quantity of refuse as reported by different installations. The only satisfactory unit of measurement for all conditions is tonnage. Supplementary data with reference to the cubic yardage of refuse should also be obtained and is of value. There are two difficulties in securing the above results. Landfill and dumping installations are not always equipped with scales. The conversion from cubic yardage to tonnage is precarious except under the most exacting supervision • since the relation between yardage and tonnage will vary widely on different days and seasons and in different locations. This condition is illustrated by the experience in New York City where the difficulty of tonnage measurements are extreme. However, the following quotation from the Annual Report of the Department of Sanitation for 1952 will illustrate the recognition of this difficulty of cubic yardage conversion and also show that progress is being made in this regard.

"Prior to 1949, quantities of refuse collected and disposed were reported in cubic yards. To increase accuracy of figures, these reports subsequently were made in pounds and tons. Since most disposal points did not have scales, some of this reporting was made in accordance with weights assigned each DS and private cartman truck.

In 1952, when it became apparent that assigned weights were inaccurate, monthly plottings and computations were made which resulted in downward, but more accurate revisions of pay-loads.

Twelve of twenty six DS disposal points now have truck-scales most of which are manually-controlled and obsolete. An automatic, electro-mechanical, tamper-proof design has been developed with the manufacturers, and will be tested in the Gansevoort marine transfer station.

The new mechanism will expedite weighing of refuse by eliminating most manual operations, including handwritten reports. This scale and related mechanism promptly will transmit accurate weight figures and other data for ready assimilation and use."

In any case the packer truck, partially filled trucks, wet weather, dry weather, differences in the characteristics of refuse from day to day, season to season and from location to location render a cubic yardage determination extremely difficult. When this defective data as to cubic yardage is converted into tonnage by a formula or guess, the inaccuracy is exaggerated and the data is valueless for comparative purposes as well as for use in plant operation. The recognition of the need for tonnage data is recognized by Federal and State Authorities, Health Departments, Municipalities and Engineers and it is felt that this recognition indicates that now is the time to initiate a pressure campaign for tonnage data.

This Society, Engineers and Incinerator Builders should use their influence to insist on tonnage records as a matter of principle and include truck scales in every installation with which they are connected. This is the only method whereby comparative data for refuse collection and disposal can be made meaningful and helpful.

Stoking

The above tabulation indicates that the circular furnace with so-called mechanical stoking has made inroads into the popularity of the old rectangular multi-cell furnace. However, it is considered that the rectangular furnaces should not be discarded under many conditions and it is recognized that some adaptation of the rectangular furnace must be made to reduce stoking labor. The Progress Report of 1952 contained a description of a new type of "stoking grate" which was first installed in Baltimore in 1952.

Each cell contains two rows of grates. The slope of the grate is 15^{o}. Every other grate in the rows is raised as a unit. After these grates lower to the normal postion, the balance of the grates in each row raise as a unit. Raising these groups of grates alternately raises and moves the refuse forward in the furnace chamber. When the material along the front wall of the furnace chamber is completely incinerated, the dump grate section along the front wall of the furnace is opened and the ash is deposited in the ash hoppers. The grate bars rise to a height of approximately 9" into the fuel bed. The end of the grate projected up into the fuel bed is protected with a heavy cast iron shield, cast integral with grates, to keep the refuse from dropping into the ash-pit. The grates are supported in cast iron bearing bars having trunnion sockets with removable caps.

The grates are raised and lowered through linkages from the dual power cylinders which are mounted on the front wall of the furnace structure. The operating handle on these cylinders is used to move the grates when desired.

The pressure unit consists of an oil pump, motor, pressure tank and reservoir. This hydraulic pressure system delivers sufficient oil of proper viscosity to operate the power cylinders with a swift, positive

action. The entire system is designed for an operating pressure of 225 pounds per square inch.

The dumping grates are at the base of the inclined grate immediately adjacent to the stoking grates. These dumping grates are of adequate size and provide for a clear, free fall of material having no projections, shafts, or mechanism exposed to impede or catch the dumped ash and non-combustible refuse. These dumping grates are raised and lowered through a linkage from separate power cylinders connected to the same pressure system that provides the power for operating the grate bars.

The claims for the effectiveness of this grate mechanism include: reduction of clinker, of "burn-down" period, and of shock to refractories; elimination of long heavy stoking irons; increase in burning rates and reduction in labor costs.

Since these statements were made in the report of 1952 various other installations of stoking grates have been made with apparently successful results in the increase of burning rates per square foot of grate surface, in the reduction of stoking and in the maintenance of steady temperatures in the installation. Reference is made to these additional plants in the notes accompanying the tabulation of recent installations and reference is made to installation numbers 2, 32, 38, 47, and 50.

In the case of installation No. 2 it is reported that a plant originally designed for 600 tons per day has been equipped with this new type grate with a resulting increased capacity of 880 tons per day. Changes have been made in the operation of cylinders to eliminate oil leakage, revised bearings have been designed and changes have been made in the pressure unit to obtain a more consistent operating pressure.

Stoking of the circular furnace also requires new consideration. It is admitted that the words "stoking grates" or "mechanical stoking", etc., can be misleading if taken too seriously. These types of apparatus are a considerable mechanical aid to stoking, but manual stoking is not thereby eliminated. One of the main problems in the stoking of large circular furnaces is due to the fact that there is one charging hole in the center of the furnace and there are no physically separated individual cells which can be separately cleaned. The temptation in actual practice is to "fill and draw" which interferes with uniform temperature maintenance and burning rates. The dual charging gate has been used in several instances in a circular furnace to produce a larger charging opening than could be supplied by a single gate. A design is now in process which uses this same dual charging gate but for another purpose, namely to provide for a charge which will fall on one half of the furnace at a time, when so desired. It is hoped that this design will, for all practical purposes, provide a circular furnace into 2 cells, one of which can be cleaned while the other is being charged. This design will be applied to the new plant for the Town of Babylon, New York and experience will indicate its value or dictate such other adaptations in charging equipment as may be suggested by its operation.

It is considered that one of the problems of the Engineer is to maintain a sufficient period of supervision of operation to develop a stoking method for any given installation which will produce the best results. No furnace, no matter how well mechanically equipped will perform its designed functions without trained manual assistance.

Incinerator Residue

The Engineer's responsibility does not end with the incineration process proper. Adequate quenching of residue and proper disposal should be a part of the Engineer's design and subject to supervision of operation by the Engineer. A poorly quenched residue and a poorly maintained residue area have, in numberless cases, depreciated the incinerator itself with no justification whatsoever. This condition is especially obvious where additions to or remodelling of an existing plant are undertaken and where bad habits have already been established with reference to the handling of incinerator residue. The Committee wishes to stress this collateral feature of incineration and can point to many installations which are subject to criticism and legal complaints stemming from improper handling of incinerator residue in and outside of the plant itself. Unless more planning is devoted to a follow-through to residue disposal, in the design and operation, incineration as against other methods of disposal will suffer.

The collapsing of tin cans is of major importance from several angles. An uncollapsed can contains water from quenching and can favor mosquito breeding. The uncollapsed can maintains breeding homes for rodents. In many installations the cans in the residue will represent about 50% of the total volume. If the cans are collapsed, the total volume of residue will obviously be materially reduced. If the residue is spread in thin layers by heavy bulldozers and the bulldozer used to compress the cans, restricted residue areas will be increased in their capacity by a large percentage. In one installation the cans are roughly screened out at the head of the ash conveyors by a pipe screen separating the vitrious residue from the cans. When a truck load of cans is dumped on the residue area, spread thin and worked over with crawler equipment, the reduction in can volume will range from 50% to 75% of loose can volume.

Fly Ash

The interception of fly ash is being imposed on incinerator design as a basic requirement and this wave of sentiment is not to be denied. The days when pieces of paper could, without comment, escape from the chimney together with other suspended solids which drop out of the flue gases within 500 feet or less of the plant, have passed.

It is considered safe to say that the attempt to drop fly ash by gravity is not taken seriously by most Engineers and most incinerator builders. Interception of fly ash by gravitation requires so low a velocity that chambers for this purpose would be extremely expensive and probably extremely ineffective since it would be difficult to reduce the gas flow to a sufficiently low velocity and yet escape by-passing and dead spaces which would defeat the theoretical design. In combustion chambers and so called expansion chambers, the interception of fly ash results principally from whipping it out at good velocities by centrifugal corce with a planned series of baffles, interference of two flows of gas and quick changes in direction. This type of design must be accompanied by retention pockets which must be kept clear. A retention pocket will fill to a certain deadline and after that the sweeping action of the

gas will preclude further accumulations of fly ash.

In general, fly ash separates itself into three types of material. That intercepted in combustion chamber pockets is generally of a grayish color and on the flaky side. When the flue gases pass through a combustion chamber into a waste boiler, the fly ash intercepted in the boiler changes color and character by becoming blackish and granular. The fly ash intercepted by a Fly Ash Arrestor is of a still different type and is a gray-black and of minute texture. Experiments looking toward the handling of combustion chamber fly ash by a hydraulic method in pipes has not proved successful in several installations. When wet, this material becomes pasty, turns brownish in color, coats pipes and when left in pipes will either form a cement coating on the pipe or else set up and clog the pipe completely. The hydraulic handling of combustion chamber fly ash could no doubt be accomplished in open channels with a considerable amount of water. In the case of the fly ash precipated in a waste heat boiler and that in a dry fly ash arrestor, both of these deposits can be handled hydraulically in pipe with a relatively small quantity of water, provided the interception tanks are agitated with tank mixers to keep the material in suspension. These two types of material can be handled hydraulically and discharged to a lagoon where the material quickly settles out and clogs the lagoon against material leakage and provides a coverage of water above the settled fly ash. When handled hydraulically with pumps, the last two types of fly ash are sufficiently abrasive to wear down the impellers of pumps and spare impellers must be available. This abrasion also affects tank mixer impellers which must frequently be replaced.

Under construction are one or two installations where elaborate water washing of flue gases is being contemplated. Reports of the operation of these installations will be of extreme interest. Fly ash interception is still in the experimental stage and untried designs can be looked upon with some skepticism.

A municipal incinerator is owned by the same municipality that dictates the rules and regulations for industrial installations. The responsibility falls upon the municipality, in its own project, to lead the way in fly ash interception although the industrial progress may seem to lag. The municipality is more vulnerable to complaint and legal action than an industry and the municipal incinerator must discharge into the air an exemplary flue gas free of detrimental fly ash, although an adjacent industry may be an obvious violator.

Charging Buckets

Several determinations have been made of the actual capacity of two and three yard buckets in terms of loose refuse discharged from the bucket. In the case of the two yard charging bucket with standard teeth, it was found that the average charge into the charging hopper amounted to about four cubic yards. It is readily admitted that when the compressed charge is released into the hopper it expands to its initial or greater volume. In the case of a three yard bucket with a short scoop plate and long teeth it was found that the average discharge from the bucket into the hopper represented a levelled off volume of 5-1/2 cubic yards.

Again, no relationship has been established between the volume of the refuse discharged into the charging hopper as compared with the original volume in the pit.

Over-fire Air

As refuse continues to include a larger percentage of combustibles, over-fire air supply becomes more eligible to consideration. Present day dry refuse discharged into a furnace operating at high temperatures quickly throws off the volitiles and demands larger quantities of air. It also developes sudden rises of temperature. Over-fire air, with thermostatic control, is to be considered for the dual purpose of supplying air for combustion and for furnace cooling.

Landscaping

Modern designs within the last few years have given consideration to landscaping of the site to architectural fitness and to building and site cleanliness. The progress in these phases of design result from public demand and will materially reduce the habitual objections to incinerator sites by its neighbors. The same requirement should be imposed upon the disposal areas in a great many cases where this area is adjacent to the incinerator. The appearance of the disposal area will be charged against the incinerator and must be given the necessary attention.

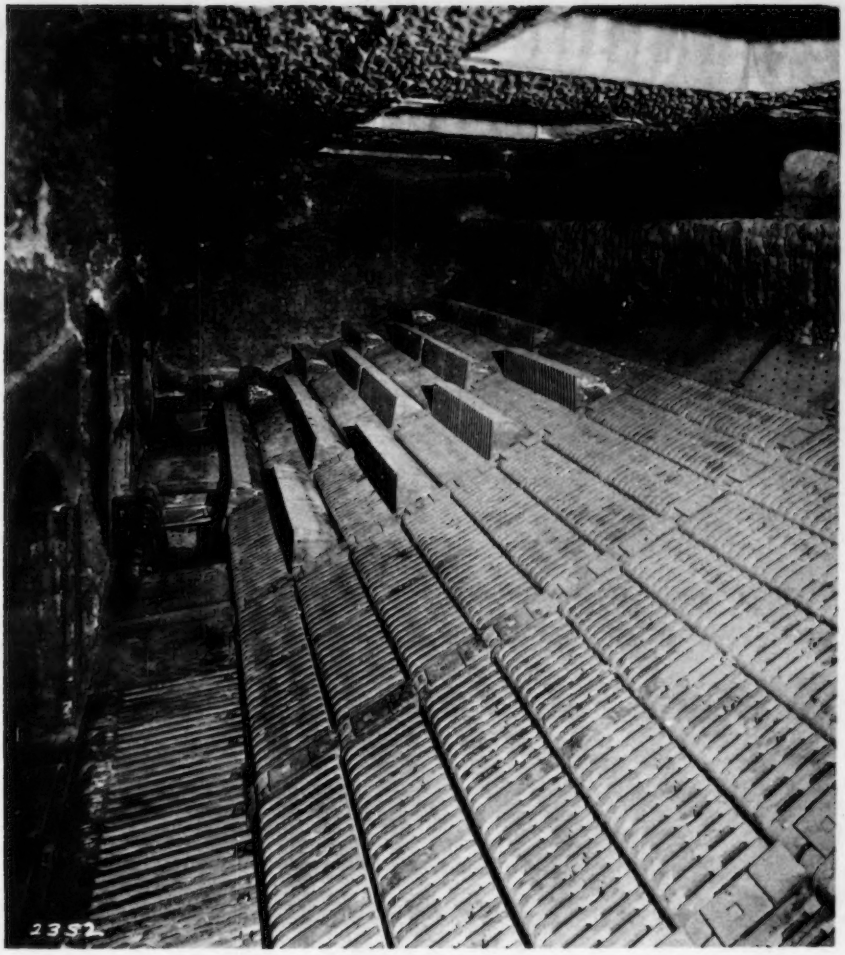

Fig. 1—Mechanical Stoker Installed at Baltimore, Md.

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